RESEARCH DEPARTMENT

A TELEVISION STORAGE TUBE WITH TWO INDEPENDENT SCANNING SYSTEMS

Report No. T-090

(1962/22)

THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

RESEARCH DEPARTMENT

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D Maurice

E.W. Taylor, M.A.

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A TELEVISION STORAGE TUBE
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SUMMARY

A storage tube having two independent scanning systems is described. This tube is designed to operate under "high-velocity" conditions; its performance is assessed when operating under these conditions and also with the potentials during one of the scans adjusted to provide "low-velocity" electrons. The theory of operation of the tube is discussed and the experimental arrangements briefly described. Methods of improving the performance of the tube by modifications to its internal structure are suggested.

1. INTRODUCTION

Many systems have been proposed by which a television signal may be stored. Some of these[1,2] rely on the afterglow of a fluorescent phosphor, and have applications in telerecording. Others[3,4] making use of a charge pattern to control the passage of electrons through a fine-mesh grid, will produce an optical display of a television picture after many hours of storage. Further systems[5,6] rely on the formation of a charge pattern on a target which may be subsequently scanned in a manner similar to that employed in a conventional camera.

This report describes a system utilizing the latter principle. The storage tube in some respects resembled an Image Iconoscope, and was intended to operate under similar electrical conditions. In particular, both the formation of the charge pattern on the target (the "writing" process) and the subsequent re-creation of an electrical signal from this charge pattern (the "reading" process) were designed to be carried out with high-velocity electron beams. Each primary electron was sufficiently energetic to produce more than one secondary electron on striking the target, which thus acquired a positive charge.

The performance of the tube was assessed for two operating conditions. In the first, high-velocity beams were used for both the writing and reading processes. In the second there was a high-velocity writing beam, but a low-velocity reading beam. In the low-velocity condition, less than one secondary electron is emitted from the target on the arrival of a primary electron so that the target acquires a negative charge during the reading process.

2. THE STORAGE TUBE

The storage tube, which is shown diagrammatically in Fig. 1, consisted of an evacuated glass bulb containing a target assembly scanned by two independent electron

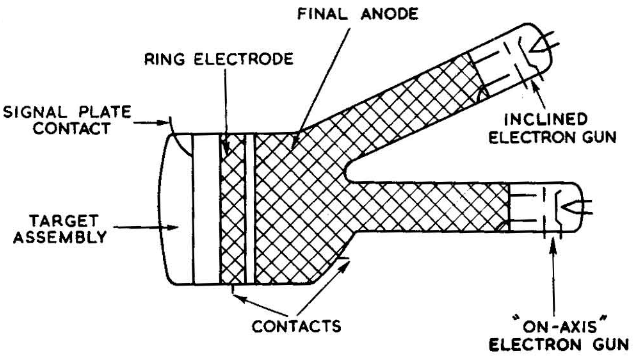


Fig. 1 - Diagram of storage tube

beams. Magnetic focusing and deflection of the beams were employed. The axis of one gun was normal to the target, while the axis of the other gun was inclined at approximately 25 degrees to the normal.

The walls of the tube were coated on the inside with a conductive layer forming a common final anode for both electron guns. This coating was connected to a contact on the glass bulb. The portion of this electrode nearest to the target assembly was isolated electrically from the rest of the layer, forming a ring electrode connected to a separate contact.

The target assembly (Fig. 2) was conventional, consisting of a sheet of mica coated, on the side remote from the electron beams, with a conductive layer (the signal plate) which was connected to the output contact. Two strip electrodes (used in a conventional Photicon tube for controlling the re-distribution of secondary

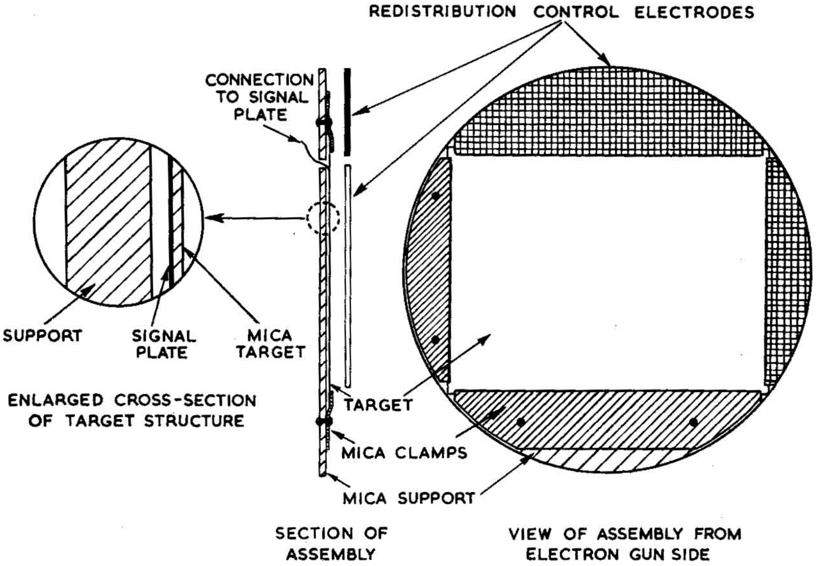

REDISTRIBUTION CONTROL ELECTRODES
CONNECTION TO SIGNAL PLATE
SUPPORT
SIGNAL PLATE
MICA TARGET
ENLARGED CROSS-SECTION OF TARGET STRUCTURE
TARGET
MICA CLAMPS
MICA SUPPORT
SECTION OF ASSEMBLY
VIEW OF ASSEMBLY FROM ELECTRON GUN SIDE

Fig. 2 - Target assembly of storage tube

electrons) were mounted along two adjacent edges of the target (on the side facing the scanning beams) and were connected to additional contacts. The output from the tube was developed across a load resistance joining the signal plate and final anode.

From the foregoing description it can be seen that the structure of the tube is very similar to that of an Image Iconoscope, with the image section replaced by an axial electron gun. Fig. 3a shows the storage tube, and Fig. 3b the assembly of the tube in a modified Image Iconoscope mounting.

3. OPERATION UNDER HIGH-VELOCITY WRITING AND READING CONDITIONS

3.1 Theory[7]

When an element of the target is struck by high-velocity scanning electrons it becomes more positive because of the liberation of secondary electrons. The electrons leaving each element come under the influence of a complex electric field. Some escape to the final anode, but many are attracted to other positively-charged areas of the target. Because these areas are those which have been most recently scanned, this redistribution of electrons takes place mainly towards the top and left-hand side of the picture.

When the potential of the target as a whole has stabilized, the number of secondary electrons leaving it equals the number of primary electrons supplied by the scanning beam. The mean potential is then very close to the potentials of the ring electrode and final anode, which are, in practice, very similar. The redistribution of the excess secondary electrons over the target produces the unwanted shading signals usually associated with high-velocity tubes.

The writing and reading processes may be carried out during alternate fields of the incoming video signal. During the writing scan, the electron beam striking the target is modulated with the signal and the reading process is carried out with an unmodulated beam.

During the writing scan, elements of the target receiving many primary electrons will acquire more positive charge than do those which receive few primary electrons. Redistribution of the secondary electrons over the target takes place in such a way as to keep the mean target potential equal to the stabilization potential. The charge pattern on the target at the end of the writing scan therefore corresponds to the picture represented by the incoming video signal superimposed on the redistribution component. Because the total number of secondary electrons emitted during the scan is a function of the mean beam current, the amplitude and geometric shape of the redistribution component depends on the mean brightness of the incoming picture.

If the subsequent reading scan is made with an unmodulated beam having a current somewhat greater than that of the peak writing beam, successive target elements are raised from the potential they achieved at the end of the writing scan to the target stabilization potential. The current required for this charging process is a function of the initial potential of the element. This current flows in the load resistance developing a signal which represents the charge pattern laid

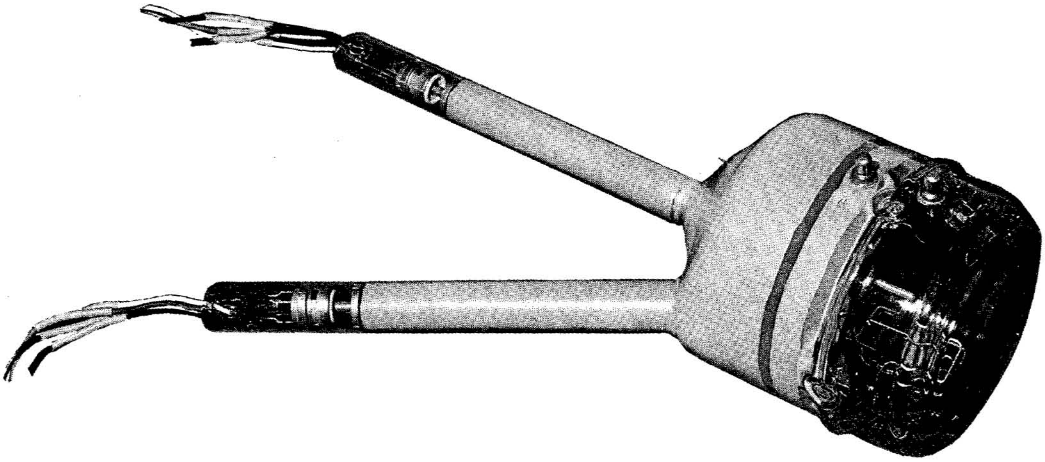


Fig. 3a - Storage tube

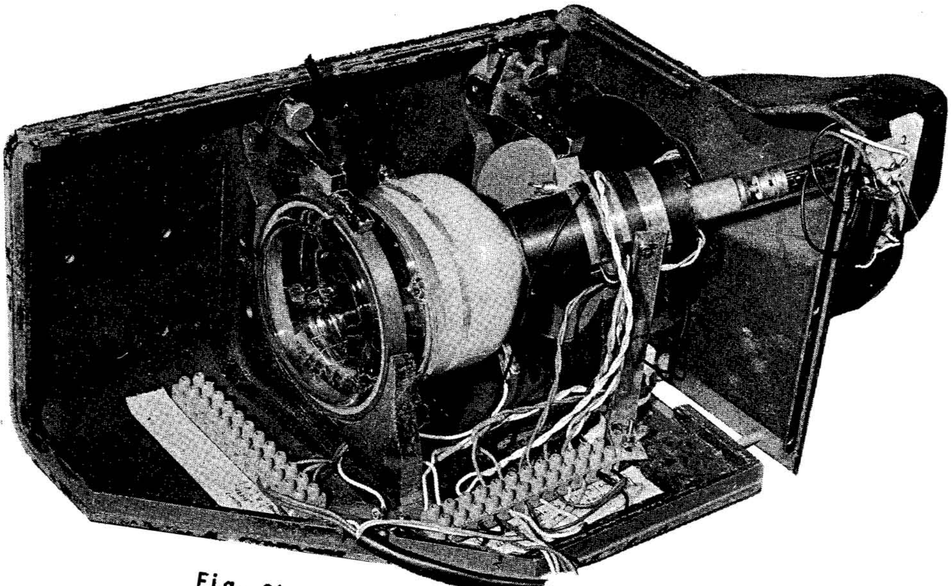


Fig. 3b - Storage tube assembly

down on the target during the writing scan; redistribution of secondary electrons also takes place during this scan. As well as building up the charge pattern that gives rise to the shading signal, the secondary electrons falling back on the target produce a current in the load resistance in opposition to that produced by the charging of the target element from which they were emitted. The output from the tube is therefore reduced.

At the end of the reading scan the charge pattern on the target consists only of the redistribution component and is therefore ready to accept the next writing scan.

Although secondary electrons are produced during both the writing and the reading scans, many more are produced during the latter cycle because the mean beam current is then much greater. This suggests that the shading signal could be reduced in amplitude by reducing the reading-beam current. Under these conditions the number of secondary electrons produced during the reading scan may not be sufficient to allow the mean potential of the target to reach its stabilization value. The shading signal will therefore be further reduced in amplitude because a greater proportion of secondary electrons will be able to reach the final anode. The wanted video signal will also be smaller, however, and in addition to this, the charge pattern on the target may not be completely removed during the reading process. This would cause blurring or "trailing" of moving pictures.

3.2 Description of Experimental System

A block schematic diagram of the equipment associated with the tube is shown in Fig. 4. Because the same beam velocity was required for both scans, only

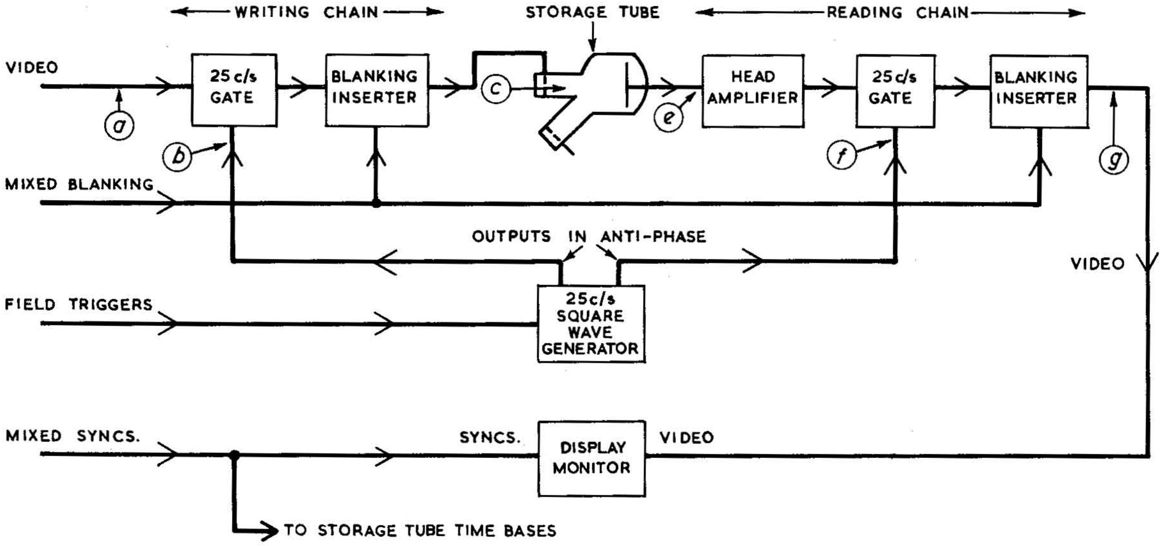


Fig. 4 - Block schematic diagram of apparatus for high-velocity writing and reading conditions

Note:- Letters in circles refer to the waveforms shown in Fig. 5

one gun was used for both writing and reading, the beam current from the other gun being suppressed. In these conditions imperfections in the scanning waveforms did not introduce any geometric distortion of the stored picture. An accelerating potential of 350 volts was used.

Waveforms at various points in the equipment are shown in Fig. 5. Alternate fields of the video waveform can be selected by means of a gate, and supplied to the modulating electrode of the storage-tube gun to form the writing signal. The subsequent reading scans are performed by an unmodulated beam. The high and low values of reading-beam current were used to obtain Figs. 6 and 7 respectively.

The output from the signal plate of the tube during the writing and reading processes are in antiphase. The read-out signal is selected by another gate, suppression pulses are inserted to remove spurious inter-line signals produced by the tube scanning circuits and the signal is passed to a picture monitor.

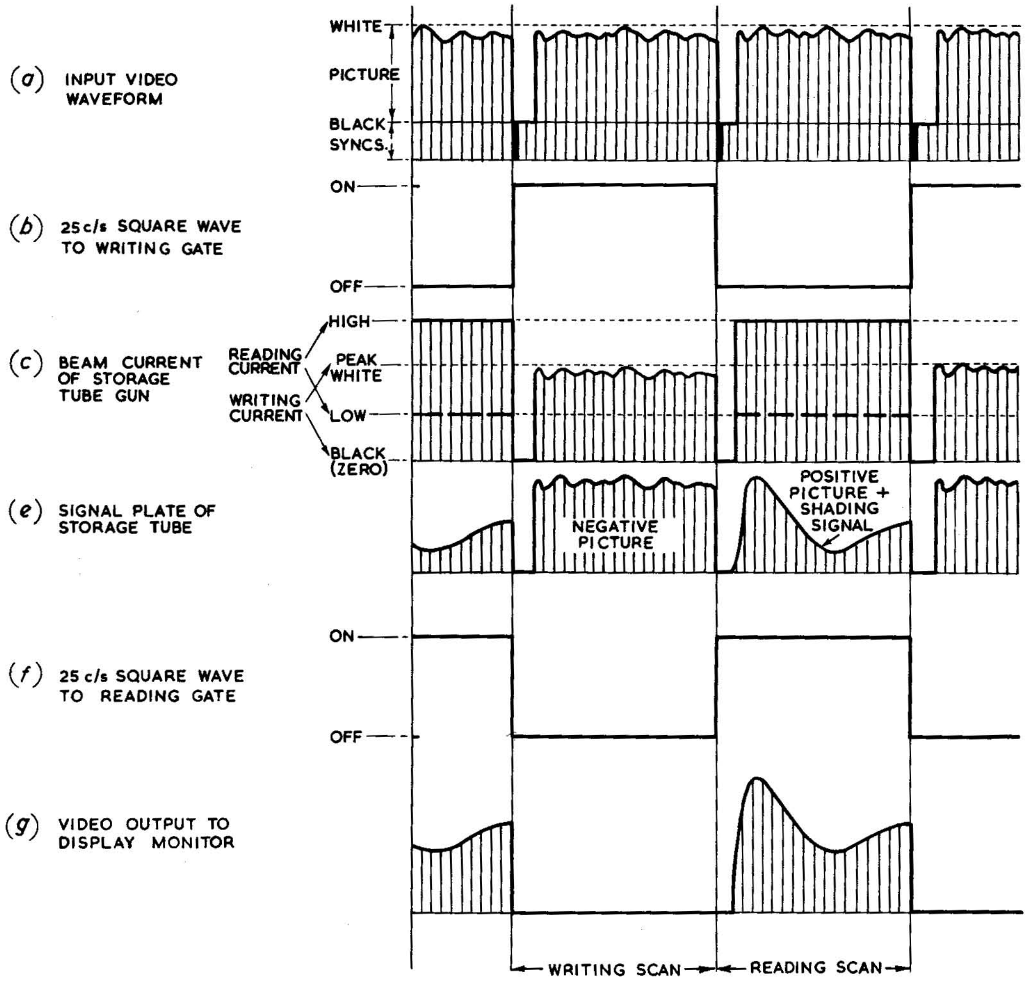

(a) INPUT VIDEO WAVEFORM
WHITE
PICTURE
BLACK
SYNCS.
ON
(b) 25 c/s SQUARE WAVE TO WRITING GATE
OFF
HIGH
(c) BEAM CURRENT OF STORAGE TUBE GUN
READING CURRENT
PEAK WHITE
WRITING CURRENT
LOW
BLACK (ZERO)
(e) SIGNAL PLATE OF STORAGE TUBE
NEGATIVE PICTURE
POSITIVE PICTURE + SHADING SIGNAL
ON
(f) 25 c/s SQUARE WAVE TO READING GATE
OFF
(g) VIDEO OUTPUT TO DISPLAY MONITOR
WRITING SCAN
READING SCAN

Fig. 5 - Waveforms in the high-velocity writing and reading conditions

Note:- Vertical shading indicates presence of line-blanking pulses

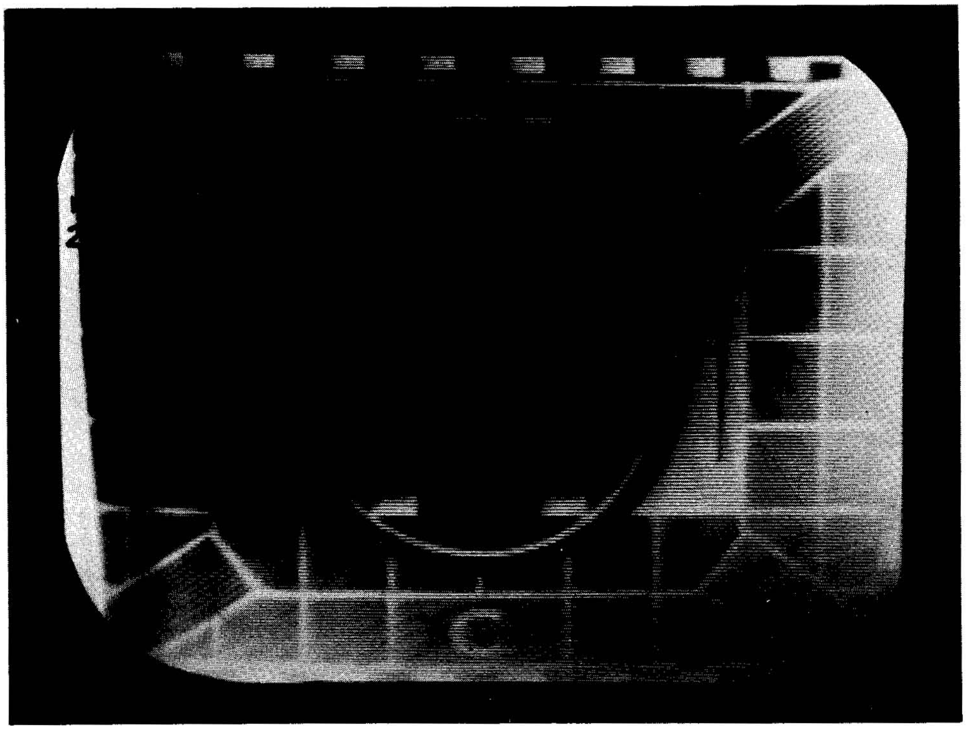


Fig. 6 - Output from storage tube under normal operating conditions

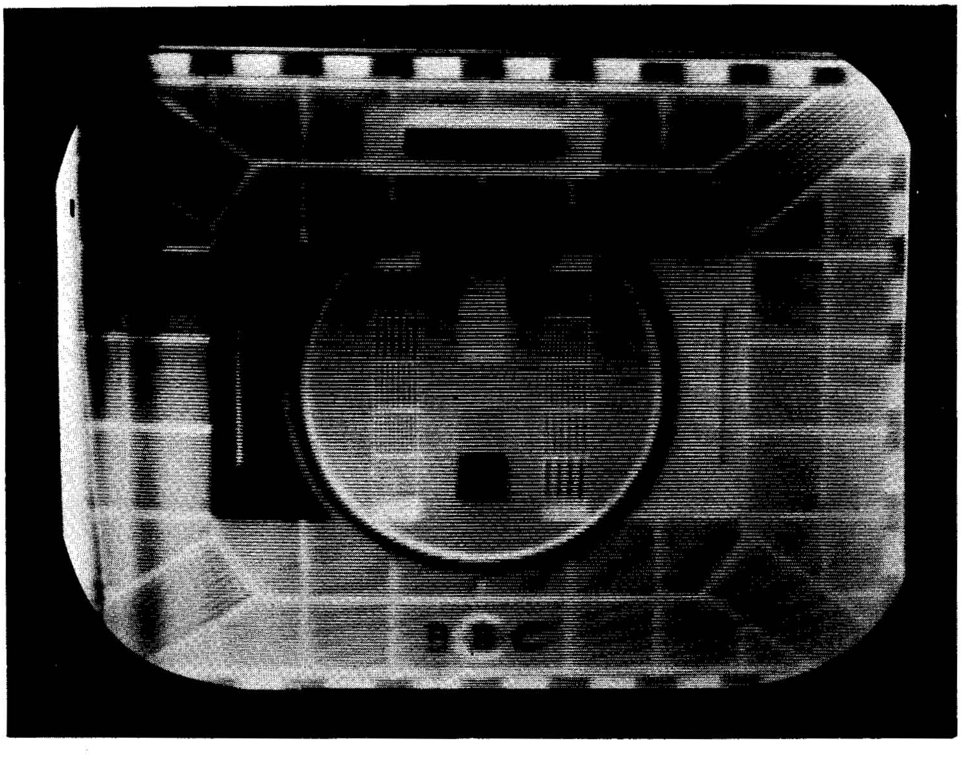


Fig. 7 - Output from storage tube with reduced reading-beam current

The equipment was supplied with a conventional 405-line signal. The scanning circuits of the storage tube produced an interlaced raster on the target, and the lines traversed by the reading beam therefore lay between those produced during the writing cycles, but this did not appear to produce a noticeable loss of output.

3.3 Practical Results

The picture obtained with the reading-beam current exceeding the peak writing-beam current is shown in Fig. 6. The main feature of this picture is the large shading signal. Variations of the potentials of the redistribution control electrodes and the ring electrode relative to that of the final anode modified the geometrical configuration of the shading signal but had little effect on its peak amplitude. Local modifications to the shading signal by the picture charge pattern on the target produced "over-writing" shadow effects.[6] These appear as white shadows above and radially outwards from the outer edges of black areas in the upper part of the picture. The occurrence of such shading signals is a serious defect, even though it would be possible to compensate partly for them by means of "tilt" and "bend" correcting waveforms. In this investigation compensation was not attempted.

The signal-to-noise ratio of the output was sufficiently good to permit equalization. When the input/output characteristic of the tube was made uniform up to a frequency of 3 Mc/s, the ratio of peak picture signal to r.m.s. noise at the output was approximately 35 dB.

Complete erasure of the picture charge pattern was obtained during the reading scan, and movement in the picture was not impaired by "trailing" effects.

When the tube was operated with reduced reading-beam current, the shading signal was considerably reduced, although the "over-writing" shadow effects were still present. Fig. 7 shows the output from the tube obtained in these conditions, the reading-beam current having a value corresponding to a mid-grey writing current. The signal-to-noise ratio of the equalized output was some 5 dB worse than when the full reading-beam current was employed. The picture charge pattern was not eliminated during one reading scan, complete erasure requiring ten or more reading cycles after the writing signal had been removed. The portrayal of movement in the stored signal was severely impaired, the trailing effect being sufficiently severe to render the output from the tube useless for television purposes.

Attempts have been made[6] to reduce the shading signals generated in a high-velocity tube by operating the target at a potential negative to that of the final anode. This was achieved by reducing the potential of the final anode by some thirty volts during the field-suppression interval preceding the writing scan and simultaneously flooding the whole of the target with electrons. Because the effectiveness of this system was limited by the relative positions of the target and the final anode, resulting in a small and non-uniform potential gradient between these electrodes, it was suggested that an improvement could be made by placing a fine mesh, connected to the final anode, in front of the target on the side facing the electron beams. This improvement would apply equally to the tube described in this report: because one electron gun was used for both writing and reading (as described in Section 3.2) the other gun could probably be made suitable for use as the source of "flooding" electrons.

4. OPERATION UNDER HIGH-VELOCITY WRITING AND LOW-VELOCITY READING CONDITIONS

4.1 Theory

If the potential of the target could be reduced to a value very negative with respect to the final anode, the secondary electrons emitted during the high-velocity scanning process would be preferentially attracted by the final anode instead of falling back on the target. The shading signals would therefore be eliminated. This condition could be achieved by operating one scanning cycle (e.g. the writing cycle) in the high-velocity condition and the other cycle (in this case the reading cycle) in the low-velocity condition; the target would acquire a positive charge during the writing scans and a negative charge during the reading scans. The final potential achieved by the target would depend on the relative amounts of positive and negative charge laid down during the two processes. If the negative charge exceeded the positive charge, the target would stabilize at the cathode potential of the electron gun supplying the low-velocity beam. The potential difference between the target and the final anode would then equal the accelerating potential applied to the low-velocity electron gun.

Because the stabilization of the target potential would be affected by low-velocity electrons, the mechanism of storage would resemble that of the "Tenicon" tube.[5] In this tube, the number of secondary electrons removed from a target element while writing is in progress is proportional to the instantaneous writing-beam current which, in turn, is a function of the video signal applied to the grid of the electron gun. All the secondary electrons are collected by the final anode and a charge pattern corresponding to the picture content of the input signal is impressed on the target. In the subsequent reading scan more low-velocity electrons are supplied to the target than are required to neutralize the most positively charged areas. Each target element is therefore discharged to the target stabilization potential, the discharge current being proportional to the potential to which each element had been raised during the writing process. This current, flowing through the load resistance, produces the output-voltage waveform.

4.2 Description of Experimental System

Fig. 8 shows a block schematic diagram of the equipment used; the waveform appearing at various points of the writing and reading chains are indicated in Fig. 9. The operation of the equipment was very similar to that described in Section 3.2, the only difference being that, during the reading scan, the beam of the high-velocity (writing) gun was suppressed and the low-velocity reading gun made operative. The accelerating potential of the writing gun was 350 V and that of the reading gun 48 V.

4.3 Practical Results

The output from the tube, when operated under these conditions, was virtually free from spurious shading signals, and a good grey scale was obtained. However, the bandwidth of the stored signal was very low, the 1·5 Mc/s bars of Test Card "C" being only just visible. The ratio of peak picture signal to r.m.s. noise was only 15 dB; this poor signal-to-noise ratio precluded any equalization.

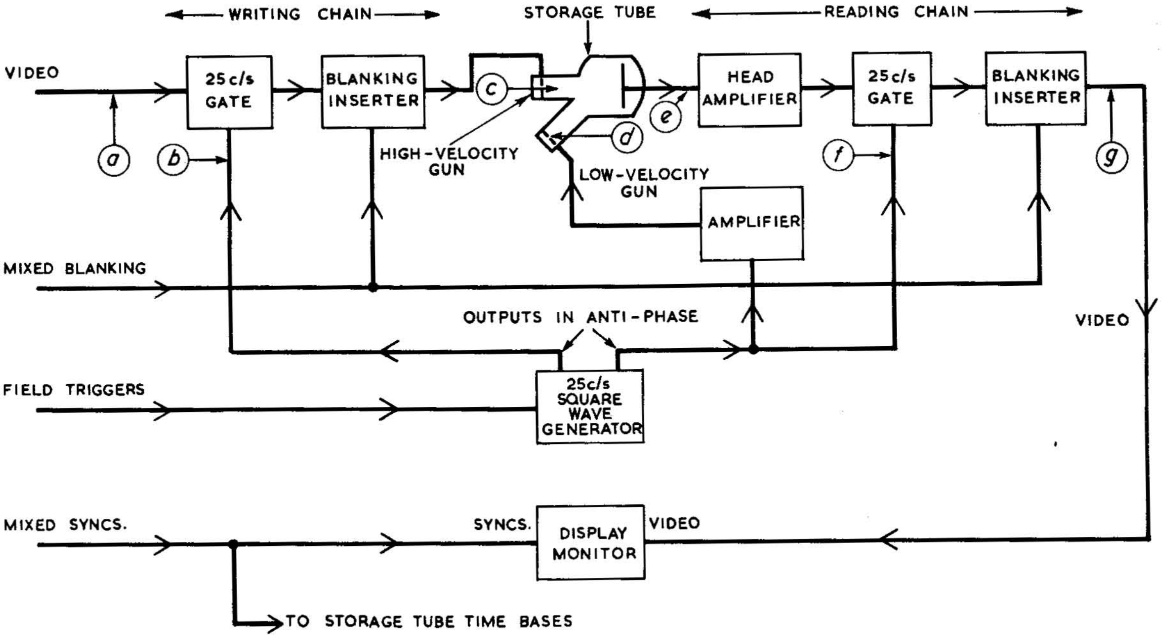


Fig. 8 - Block schematic diagram of apparatus for high-velocity writing and low-velocity reading conditions

Note:- Letters in circles refer to the waveforms shown in Fig. 9

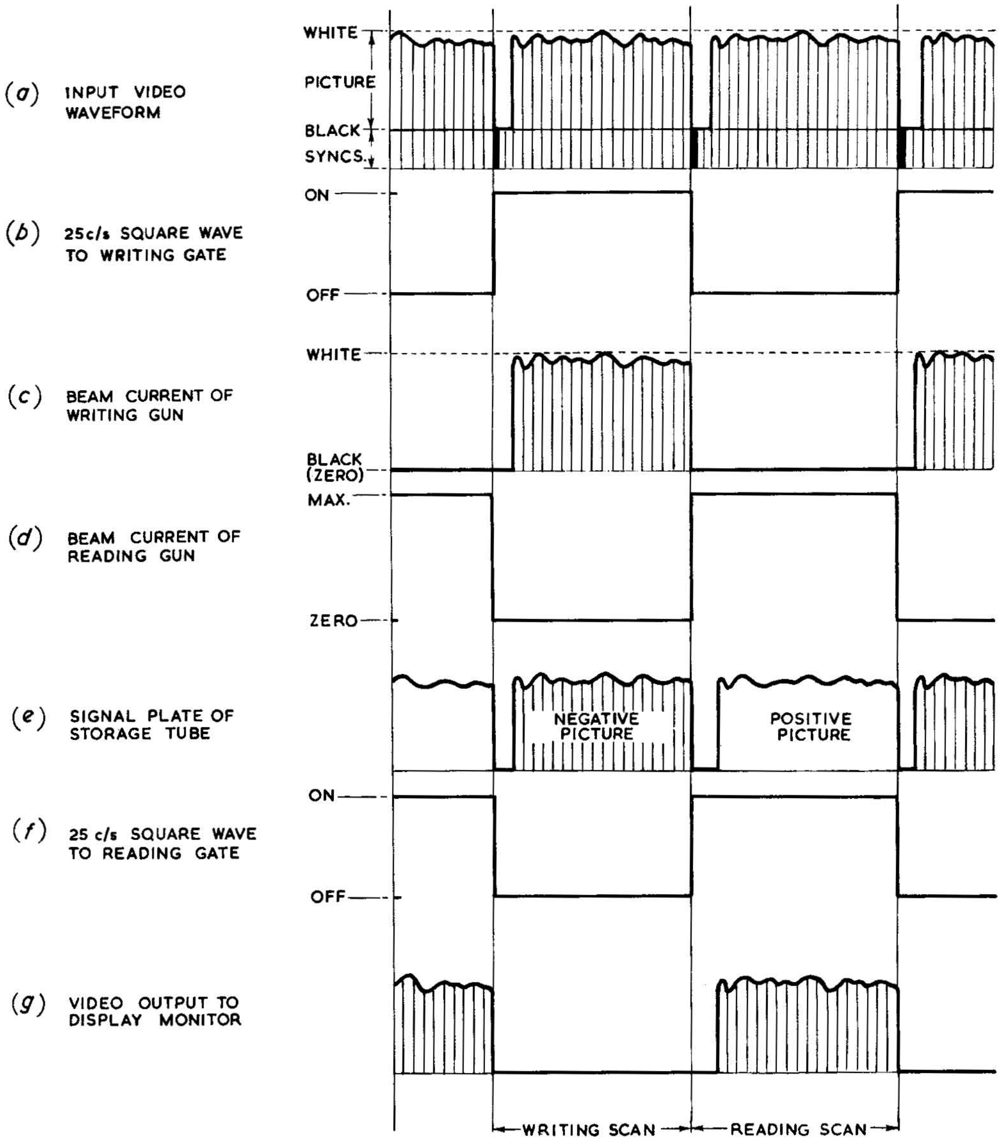
In order that the reading gun should generate a beam of low-velocity electrons, it was operated with a very low accelerating potential. The defects in the stored signal were caused by the poor focus and low beam current of the electron gun when operated under these conditions, for which the gun had not been designed.

In addition to these defects, which were in themselves sufficient to make the stored pictures unacceptable for television purposes, very severe "trailing" was produced during picture movement. This was presumably caused by the low reading-beam current permitting only partial discharge of the target during one reading scan, as described in Section 3.3.

The storage tube appears inherently capable of good resolution and signal-to-noise characteristics and its performance, when operating under low-velocity reading conditions, is apparently limited only by the behaviour of the reading electron gun. The full capabilities of the tube, without the presence of the shading signals produced when operating under high-velocity reading conditions, could probably be realized if a well-focused low-velocity reading beam of adequate intensity could be provided.

5. CONCLUSIONS

In the normal mode of operation, with high-velocity writing and reading scans, the output signal from the tube has a satisfactory bandwidth and signal-to-


(a) INPUT VIDEO WAVEFORM
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WHITE
BLACK (ZERO)
(d) BEAM CURRENT OF READING GUN
MAX.
ZERO
(e) SIGNAL PLATE OF STORAGE TUBE
NEGATIVE PICTURE
POSITIVE PICTURE
(f) 25 c/s SQUARE WAVE TO READING GATE
ON
OFF
(g) VIDEO OUTPUT TO DISPLAY MONITOR
WRITING SCAN
READING SCAN

Fig. 9 - Waveforms in the high-velocity writing and low-velocity reading conditions

Note:- Vertical shading indicates presence of line blanking pulses

noise ratio. Nevertheless, the presence of a shading component of large amplitude makes the tube unsuitable for most television purposes. The shading signal can be reduced substantially by alteration of the operating conditions of the tube, but other factors then severely degrade the output signal. In particular, smearing or "trailing" of moving pictures can be sufficient to make all but the slowest-moving scenes completely unrecognizable.

Modifications to the internal structure of the tube might result in a reduction of the shading component to a level where a good input/output characteristic could be obtained under "high-velocity" conditions. An improved performance using "low-velocity" reading could probably be effected by incorporating a suitably designed reading gun.

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